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Water Loss in Egypt Based on the Lake Nasser Evaporation and Agricultural Evapotranspiration

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Abstract

One of the most significant and broadly effects of climate variability in water budget are changes in evaporation and/or evapotranspiration. This study aims to estimate of water loss based on Lake Nasser evaporation and agricultural evapotranspiration in Egypt using climate and satellite data during the period from 2001 to 2013, and study the effect of climate change on water loss in Egypt using the (ECHAM 6, Rcp. 4.5 scenario) during the period (2015-2025). This estimation integrates remote sensing, Geographic Information System (GIS) techniques, and MODIS images. The results showed that the water loss over Lake Nasser is ranged from about 12.3 to 12.9 billion m^3 and from about 16.3 to 17.4 billion m3 by using data from MERRA images and ECMWF (ERA-Interim), respectively. The water loss over agricultural lands is ranged from about 34.4 to 42.4 billion m3 and from about 44.2 to 48.4 billion m^3 by using data from Land Surface Temperature (MODIS) and ECMWF (ERA-Interim), respectively. The total annual water loss will be increase in the future with a noticeable values, where it ranged from about 61.5 to 66 billion m^3 per year during (2015-2025) while it ranged from about 53 to 57.5 billion m^3 per year during (2001-2013), and the highest amount of total water loss during the study period was observed in the year of 2021. Lake Nasser evaporation and agricultural evapotranspiration are an important contributing factor to the lake water budget and accordingly it is very important to be addressed according to the most recent technologies in this respect.

Keywords: Evaporation; Evapotranspiration; Remote sensing; MODIS/Terra satellite data; Hargreaves equation; Water loss; Climate change.

1. Introduction

Evaporation and evapotranspiration are major components of the water cycle and water balance, being major variables in analyzing the variations of the water level and volume stored in a lake. Studying them allows a better knowledge and understanding of the mechanisms and regularities that guides the water circulation in nature and also its associated processes. (Stan *et al.,* 2016). The most effective water loss processes are the evaporation from natural and artificial water bodies, and evapotranspiration from the land that represent the main process in the climate system and a nexus of the water, carbon cycles and energy. Global land ET returns around 60% of annual land precipitation to the atmosphere (Oki *et al.*, 2006). Evapotranspiration (ET) is the term used to represent the removal of water through a combination of direct evaporation and vegetation transpiration (Elfadli, 2018). Evapotranspiration varies widely through both time and space, along with the meteorological and biological factors that push it. Spatial and temporal heterogeneity of vegetation cover and function, as well as differences in available energy and water, all influence the rate at which ET occurs (Khalil *et al.,* 2015), it is essential to understand the changing patterns in reference evapotranspiration (ET0) and its relation to climate variables. (Song *et al.,* 2017). Lake Nasser evaporation is a major concern for most of the water specialists in Egypt because lake evaporation is a significant fraction (about 20%) of the Egyptian water resources estimated by 55.5 BCM and there is no accurate estimation of lake evaporation values and also different approaches have been discussed to reduce lake evaporation but it was not practical to study any of these approaches without having accurate evaporation estimation (Sherine 2010). Remote Sensing (RS) and Geographical Information System (GIS) data play a rapidly increasing role in the agriculture, hydrology and water resources development (Hala and Sherine 2010). Satellite remote sensing provides information on surface radiative properties, surface temperature and vegetation cover at the regional scale. Several attempts have been made in the past to evaluate the amount of evaporation in general from land surfaces (evapotranspiration) and open water surfaces (evaporation) in specific. Remote sensing images have been increasingly used to monitor and analyze inundation and fluctuation of playa lakes (Bryant and Rainey, 2002; Castaneda *et al.,* 2005; French *et al.,* 2006). Most of the technologies used to estimate evaporation from open water bodies are either aerodynamic based techniques or energy balance techniques. Even though estimating evaporation from open water surfaces remains a very uncertain process. The present work investigates the water loss in Egypt from agricultural lands evapotranspiration and Lake Nasser evaporation during the period from 2001 to 2013 based on satellite and climate data and studying the effect of climate change on water loss during the period from 2015 up to 2025.

2. Materials and Methods

2.1 Dataset

a) Current climate data

Calculating the water loss from climate data has been done based on data from ECMWF (ERA-Interim) during the period from 2001 to 2013. ECMWF periodically uses its forecast models and data assimilation systems to 'reanalyse' archived observations, creating global data sets describing the recent history of the atmosphere, land surface, and oceans. ERA-Interim is a global atmospheric reanalysis from 1979 to present available at (http://apps.ecmwf.int/datasets/data/interim-full-daily/).

b) Future climate data

The future climate data in this study represented by ECHAM 6 model with the scenario of Rcp. 4.5 during the period from 2015 to 2025. ECHAM 6 is the sixth generation of the atmospheric general circulation model ECHAM, developed by the Max Planck Institute for Meteorology (MPI-M) in Hamburg, Germany. The original ECHAM model branched from an early release of the ECMWF (European Center for Medium Range Weather Forecasts) model to climate studies (Roeckner *et al.*,1989). Hence its name, ECHAM, which fuses the EC from ECMWF and HAM for Hamburg. Since its inception, ECHAM has served as the atmospheric component of a coupled modeling system.

c) Satellite data

Calculating the water loss from satellite data has been done based on two sources

(i) MERRA monthly surface evaporation for Lake Nasser during the period from 2001 to 2013 which is available at (http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl?LOOKUPID_List=MAI1NXINT)

The MERRA is a NASA reanalysis for the satellite era using a major new version (V5) of the Goddard Earth Observing System (GEOS) Data Assimilation System (DAS). This MERRA Instance of Giovanni focuses on visualizing and analyzing the MERRA hourly 2D data from the MERRA HISTORY COLLECTIONS. It focuses on historical analyses of the hydrological cycle on a broad range of weather and climate time scales. MERRA data resolution is 2/3 longitude and 1/2 latitude degrees (Figure 1).

(ii) The Moderate Resolution Imaging Spectrometer (MODIS) Land Surface Temperature LST - 8 day with resolution 1 Km and Normalized Difference Vegetation NDVI – 16 day with resolution 500 m on the Terra instrument for the period from Jan. 2001 up to Dec. 2013 which are available at (http://reverb.echo.nasa.gov/reverb/) (Figures 2 and 3).

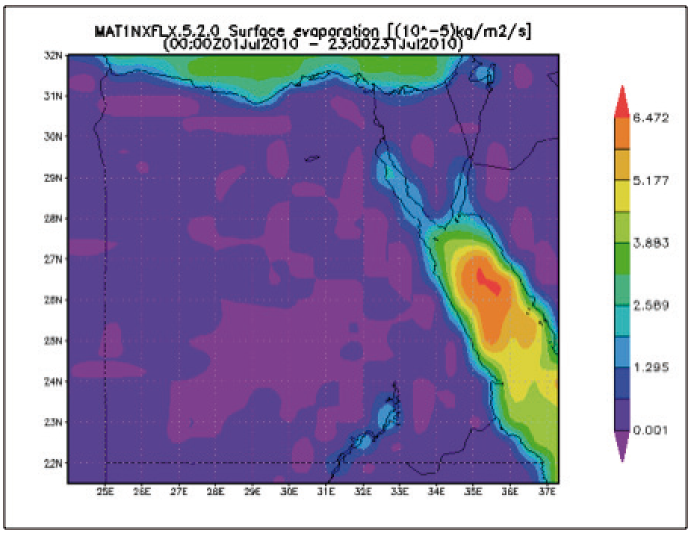

Figure 1 Sample of MERRA surface evaporation data (July 2010)

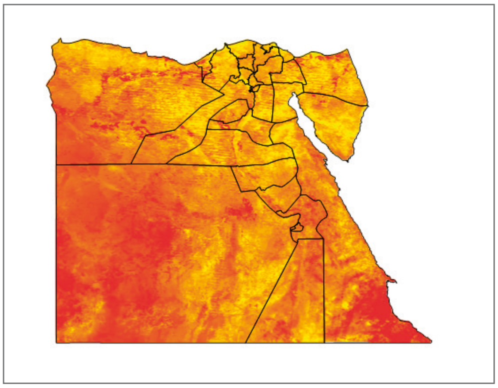

Figure 2 Land Surface Temperature (LST)

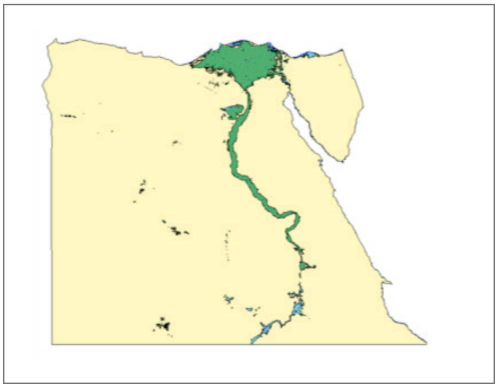

Figure 3 The agricultural area over Egypt was estimated from NDVI satellite images.

2.2 Methodology

Estimating the water loss in Egypt is based mainly on calculating the water that is loss in the term of evapotranspiration from the agriculture and evaporation from Lake Nasser

a) Calculation of evapotranspiration

Evapotranspiration has been calculated from climate data of ECMWF (ERA-Interim) and MODIS satellite data using the Hargreaves method (Hargreaves and Samani, 1985) which depends mainly on average, maximum, and minimum temperatures, with extraterrestrial radiation calculated as a function of latitude and day of the year (Itenfisu *et al.*, 2003).

The HG equation can be written as

$$ET_{o_{HG}} = 0.0023 \times R_a \times (T + 17.8) \times (\sqrt{T_x - T_n}) \qquad (1)$$

Where,

ET_{o_HG} : Hargreves evapotranspiration;

R_a : Extraterrestrial radiation (calculated from [eq. 2]);

T: Average temperature;

Tn: Minimum temperature; and

Tx: Maximum temperature.

The Extraterrestrial radiation Ra for each day of the year and for different latitudes is estimated from the solar constant, the solar declination and the time of the year by:

$$R_a = \frac{24\,(60)}{\pi} G_{sc}\, d_r\, [\omega_s \sin(\varphi) \sin(\delta) + \cos(\varphi) \cos(\delta) \sin(\omega_s)] \qquad (2)$$

G_{sc} Solar constant = 0.0820 $MJ/m^2/min$

d_r Inverse relative distance Earth-Sun (Equation 4),

ω_s Sunset hour angle (Equation 6) [rad],

φ Latitude [rad] (Equation 3),

δ Solar declination (Equation 5) [rad].

The latitude φ expressed in radians is positive for the northern hemisphere and negative for the southern hemisphere. The conversion from decimal degrees to radians is given by:

$$[\text{Radians}] = \frac{\pi}{180} [\text{decimal degrees}] \qquad (3)$$

The inverse relative distance Earth-Sun d_r and the solar declination δ are given by:

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365}J\right) \quad (4)$$

$$\delta = 0.409 \left(\frac{2\pi}{365}J - 1.39\right) \quad (5)$$

Where J is the number of the day in the year. It must be between 1 (1 January) and 365 or 366 (31 December).

The sunset hour angle ω_s is given by:

$$\omega_s = \arccos\left[-\tan(\varphi)\tan(\delta)\right] \quad (6)$$

Daylight hours (N) are given by:

$$N = \frac{24}{\pi}\omega_s \quad (7)$$

Where ω_s is the sunset hour angle in radians, as given by Equation 6.

b) Calculation of evaporation

We select four points in the lake at different geographic location to represent the average evaporation multiplied by lake area (5000 Km^2). The selected points, coordinates, and the lake width are shown in Figure 4 and Table 1.

The surface evaporation from the lake Nasser during the period from 2001 up to 2013 has been estimated by analyzing the MERRA surface evaporation over the lake (as a satellite data source) and the method of Stephens–Stewart (McGuinness and Bordne, 1972; Rosenberry *et al,* 2007) after adjusted in Egypt (EWA Egypt, 2016) using the ERA-Interim data (as a climate data source).

Table 1 The selected points coordinate and width in the Lake Nasser.

Point Num.	Lat. (deg.)	Lon (deg.)	Width (km)
1	23.70	32.90	10.91
2	23.08	32.78	20.63
3	22.68	32.43	3.90
4	22.40	31.77	22.00

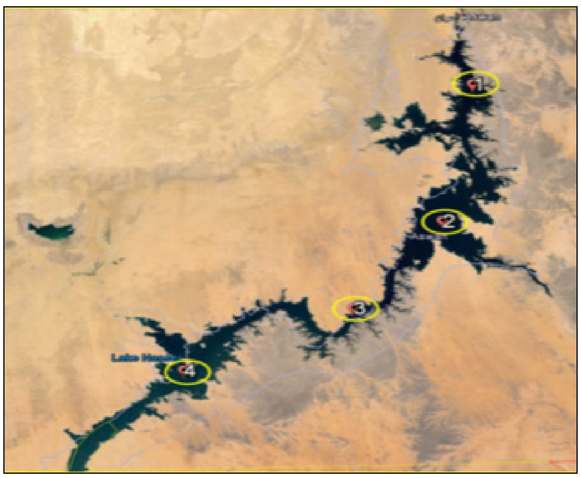

Figure 4 The location of the selected four points in the Lake Nasser.

The Stephens–Stewart equation can be written as

$$E = (0.0082\ Ta - 0.19)\ (Qs \times 3.495 \times 10^{-2})$$

Where

E: Stephens–Stewart evaporation;

Ta = air temperature (°C);

Qs = solar radiation (W/m^2)

c) Studying the effect of climate change on water loss

The Regional Climate Model RegCM4 which developed from the Earth System Physics (ESP) section of the ICTP has been used in dynamical downscaling on the Egypt with a horizontal resolution 50 Km grids spacing with 18 vertical levels for the Rcp4.5 scenario of the ECHAM6 GCM during the period from 2015 up to 2025 to estimate the water loss in Egypt from agriculture and Lake Nasser during the period (2015-2025).

3. Results and discussions

3.1 Water Loss from Agriculture

Water loss from agriculture lands has been expressed in the terms of evapotranspiration which describe the loss of water from the Earth's surface to the atmosphere by the combined processes of evaporation from the open water bodies, bare soil, and plant surfaces, etc. and transpiration from vegetation or any other moisture containing living surface. Table 2 shows the estimated area of the agricultural lands in Egypt during the period (2001-2013) which extracted from MODIS- NDVI for each year from January to December. The calculated ETo from the MODIS and ECMWF (ERA-Interim) climate data over the estimated agricultural lands during the period from 2001 up to 2013 are shown in Tables 3 and 4 and it's indicated that the lowest value of evapotranspiration was observed in December and January and the highest value is observed in June month during the study period in both sources, while the highest average annual was found in the year of 2003 by MODIS data and in the year of 2010 by ERA-Interim data. The variation between the results of the two sources is a reference to the change of the temperature in the two sources where the applied approach in estimating the evapotranspiration is mainly function in the temperature variable.

Figures 5 (a and b) show the total annual of water loss from agricultural lands during the studied period using MODIS and ECMWF (ERA-Interim) climate data and it has been observed that, MODIS source found the annual water loss over agricultural lands in Egypt is ranged from about 34.4 to 42.4 billion m3 during the studied 13 years, and the highest/lowest year in water loss is recorded in 2012/2004, while the results of ERA-Interim data found the annual water loss over agricultural lands ranged from about 44.2 to 48.4 billion m^3, and the highest/lowest year in water loss is recorded in 2012/2002.

Table 2 The agricultural lands areas in Egypt during the period (2001-2013) using Normalized Difference Vegetation NDVI from MODIS.

Agricultural lands areas (x10[6] Acre)													
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
2001	8.6	8.5	8.5	8.2	6.1	7.4	8.0	8.0	7.4	7.2	7.8	8.3	7.8
2002	8.5	8.6	8.5	7.8	6.7	7.6	8.2	8.2	7.7	6.6	7.8	8.4	7.9
2003	8.6	8.5	8.6	8.1	7.1	7.4	8.2	8.2	7.7	6.2	8.0	8.3	7.9
2004	8.5	8.6	8.7	8.4	6.0	7.5	8.4	8.4	8.1	6.6	8.1	8.3	8.0
2005	8.7	8.8	8.8	8.5	7.2	7.8	8.4	8.5	7.9	6.1	8.0	8.4	8.1
2006	8.7	8.8	8.8	8.5	7.2	7.7	8.4	8.5	8.0	5.9	7.9	8.5	8.1
2007	8.8	8.9	8.9	8.6	7.3	7.7	8.4	8.5	7.9	7.1	8.0	8.5	8.2
2008	8.8	8.9	9.0	8.6	6.7	7.7	8.5	8.6	7.7	6.3	8.0	8.7	8.1
2009	8.9	8.9	9.0	8.5	6.6	7.7	8.5	8.4	7.9	6.2	8.1	8.7	8.1
2010	8.9	8.8	8.9	8.3	6.6	7.9	8.5	8.2	7.7	6.1	8.1	8.5	8.1
2011	9.0	9.0	9.0	8.7	6.9	7.4	8.6	8.6	8.1	6.4	8.0	8.8	8.2
2012	9.1	9.0	9.3	8.9	8.0	7.5	8.6	8.6	8.1	7.2	8.4	9.0	8.5
2013	9.3	9.3	9.3	8.8	6.7	7.9	8.7	8.7	8.1	6.2	8.3	9.1	8.4
Ave	8.8	8.8	8.9	8.5	6.8	7.6	8.4	8.4	7.9	6.4	8.0	8.6	

Table 3 The average ETo (mm/day) from the agricultural lands in Egypt during the period (2001-2013) using Land Surface Temperature from MODIS

Average ETo from the agricultural lands (mm/day) using Land Surface Temperature from MODIS.													
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
2001	0.7	1.9	3.3	3.8	5.2	6.8	3.5	3.3	3.6	3.1	0.6	1.2	3.1
2002	1.1	1.3	3.7	5.0	4.2	5.8	4.3	3.5	2.9	2.9	1.4	0.8	3.1
2003	0.9	1.6	2.9	4.3	5.0	6.3	5.5	5.6	4.6	1.3	2.2	1.5	3.5
2004	0.7	2.3	2.7	4.1	3.8	5.3	4.2	3.2	3.8	2.0	2.5	1.0	3.0
2005	1.1	2.4	1.9	4.5	5.3	5.8	4.3	5.8	3.5	3.4	1.3	1.6	3.4
2006	1.2	2.2	0.9	4.3	6.4	5.0	3.5	5.8	3.2	3.5	1.1	1.4	3.2
2007	1.0	2.5	2.6	4.3	4.1	6.3	5.8	4.3	4.5	2.2	2.4	1.1	3.4
2008	0.9	1.9	3.7	4.3	4.6	4.0	5.2	6.6	3.8	2.8	1.6	1.5	3.4
2009	0.8	1.5	2.9	3.5	5.5	6.5	5.2	5.0	3.9	2.8	1.7	1.1	3.4
2010	1.1	2.4	3.4	4.5	4.7	3.8	6.0	3.9	4.3	1.6	1.7	0.8	3.2
2011	0.9	2.0	2.8	4.2	5.3	5.3	5.2	4.5	3.6	3.0	1.9	0.9	3.3
2012	0.8	1.6	3.3	4.4	4.4	6.3	5.5	4.6	4.2	2.0	2.9	1.1	3.4
2013	0.6	1.7	3.1	4.0	3.9	5.5	5.2	5.4	2.9	2.6	1.9	1.2	3.2
Ave	0.9	1.9	2.9	4.2	4.8	5.6	4.9	4.7	3.8	2.6	1.8	1.2	

Table 4 The average ETo from the agricultural lands in Egypt during the period (2001-2013) using climate data from ECMWF (ERA-Interim).

Average ETo from the agricultural lands (mm/day) using climate data from ECMWF (ERA-Interim)													
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
2001	1.9	2.5	3.7	4.3	5.5	5.9	5.6	5.3	4.6	3.2	2.3	1.8	3.9
2002	1.6	2.5	3.4	4.2	5.4	5.7	5.8	5.2	4.8	3.2	2.4	1.8	3.8
2003	2.0	2.2	3.0	4.3	5.7	6.1	5.5	5.3	4.6	3.4	2.3	1.8	3.9
2004	1.7	2.5	3.4	4.2	5.5	5.8	5.8	5.1	4.6	3.4	2.3	1.9	3.8
2005	1.8	2.4	3.3	4.3	5.4	5.7	5.7	5.2	4.7	3.2	2.3	1.9	3.8
2006	1.8	2.5	3.4	4.2	5.3	6.0	5.4	5.4	4.7	3.4	2.2	1.8	3.8
2007	1.8	2.4	3.3	4.2	5.4	6.0	5.7	5.2	4.4	3.5	2.4	1.9	3.8
2008	1.7	2.3	3.7	4.5	5.4	6.2	5.5	5.4	4.7	3.2	2.4	1.9	3.9
2009	1.9	2.6	3.3	4.4	5.1	6.2	5.6	5.2	4.6	3.5	2.3	1.9	3.9
2010	2.0	2.8	3.5	4.5	5.5	6.0	5.4	5.4	4.8	3.6	2.5	2.0	4.0
2011	1.8	2.4	3.3	4.1	5.3	5.7	5.7	5.2	4.6	3.3	2.1	1.8	3.8
2012	1.7	2.3	3.1	4.6	5.6	6.1	5.7	5.4	4.6	3.5	2.4	1.9	3.9
2013	1.9	2.6	3.8	4.2	5.8	6.1	5.4	5.4	4.6	3.3	2.4	1.8	3.9
Ave	1.8	2.5	3.4	4.3	5.4	6.0	5.6	5.3	4.6	3.4	2.3	1.9	

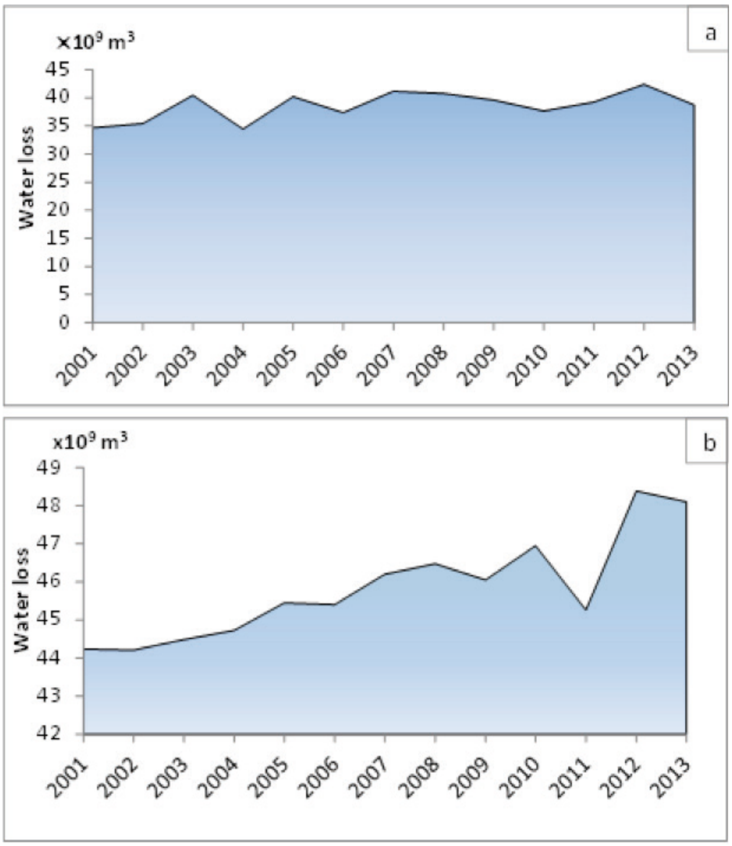

Figure 5 The total annual of water loss from agricultural lands using Land Surface Temperature from MODIS (a) and climate data from ECMWF (ERA-Interim) (b).

3.2 *Water Loss from Lake Nasser*

Water loss from Lake Nasser has been expressed in the terms of evaporation which describe the loss of water from the water's surface to the atmosphere. Tables (5 and 6) showed the average evaporation from Lake Nasser in Egypt during the period (2001-2013) using satellite data from MERRA images and climate data from ECMWF (ERA-Interim). The results indicated that the lowest value of evaporation during the period (2001-2013) was observed in December and January in both sources that represent the coldest and rainiest months in Egypt, while the highest value is observed in the month of June by MERRA data and in June and July by ECMWF (ERA-Interim) data as these months representing the hottest period of the year in Egypt and that is increase the evaporation in them. Also, it has observed that the highest average annual was found in the year of 2008 by MERRA data and in the year of 2010 by ERA-Interim data while the lowest average annual was found in the year of 2011 by both sources.

Figures 6 (a and b) show the total annual of water loss from Lake Nasser during the studied period and the results indicated that the highest water loss was in 2008 and 2010 using MERRA images and ECMWF (ERA-Interim), respectively. The water loss over Lake Nasser is ranged from about 12.3 to 12.9 billion m3 and from about 16.3 to 17.4 billion m^3 by using data from MERRA images and ECMWF (ERA-Interim), respectively.

Table 5 The average evaporation from Lake Nasser in Egypt during the period (2001-2013) using satellite data from MERRA images.

Average evaporation from the lake (mm/day) using satellite data of MERRA images													
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
2001	3.2	4.6	5.8	7.9	9.0	9.7	9.1	9.4	7.9	7.0	4.3	3.6	6.8
2002	3.6	4.9	6.1	7.8	8.3	10.1	9.0	9.5	8.0	7.4	4.7	3.4	6.9
2003	3.2	4.9	5.8	7.6	8.5	10.1	9.4	9.3	7.9	6.8	5.2	3.5	6.8
2004	3.1	4.3	6.3	7.9	8.6	9.9	9.2	9.0	7.3	7.2	5.5	2.9	6.8
2005	3.1	4.8	6.1	8.1	8.5	10.1	9.3	9.4	7.8	7.1	3.8	3.8	6.8
2006	3.8	4.3	6.6	6.8	8.8	9.8	9.7	8.9	7.8	7.6	4.4	3.3	6.8
2007	2.9	4.5	5.9	7.3	9.1	9.6	9.4	9.2	7.9	7.3	4.6	3.5	6.8
2008	3.7	4.2	6.5	9.2	9.3	10.2	9.5	8.8	8.2	7.1	4.3	3.5	7.0
2009	3.0	5.2	6.1	7.7	10.9	9.7	9.5	9.2	7.6	6.8	4.6	3.0	6.9
2010	3.3	5.2	6.4	7.5	8.8	9.8	9.7	9.5	7.4	7.3	4.9	3.7	6.9
2011	3.2	5.0	6.0	7.3	8.7	10.0	9.2	9.4	7.5	7.2	4.2	3.0	6.7
2012	3.1	5.0	6.0	7.7	8.7	10.1	9.7	9.2	7.5	7.0	5.5	3.4	6.9
2013	3.3	4.8	6.0	7.5	8.8	10.0	9.5	9.0	8.0	6.7	3.9	3.8	6.8
Ave	3.3	4.7	6.1	7.7	8.9	9.9	9.4	9.2	7.7	7.1	4.6	3.4	

Table 6 The average evaporation from Lake Nasser in Egypt during the period (2001-2013) using climate data from ECMWF (ERA-Interim).

Average evaporation from the lake (mm/day) using climate data from ECMWF (ERA-Interim)													
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave
2001	4.8	5.3	8.5	10.5	12.0	12.3	12.7	12.6	11.0	8.3	5.9	4.6	9.0
2002	4.1	5.9	8.2	10.4	11.7	12.6	13.0	12.5	11.2	8.7	6.3	4.6	9.1
2003	5.0	5.1	7.2	10.3	12.5	12.8	12.7	12.5	11.0	8.9	6.3	4.6	9.1
2004	4.6	5.5	8.2	10.3	12.6	12.6	12.7	12.0	10.7	8.9	6.1	4.6	9.1
2005	4.5	5.9	7.9	10.5	11.7	12.8	12.8	12.5	10.9	8.6	5.8	5.3	9.1
2006	5.0	5.9	8.0	9.9	12.0	13.1	12.4	12.5	11.0	8.7	5.6	4.3	9.0
2007	4.5	5.5	7.8	10.4	12.2	12.7	12.8	12.4	10.4	8.8	6.2	4.7	9.0
2008	4.5	5.2	8.8	10.7	11.9	13.1	12.7	12.4	11.1	8.4	6.4	5.0	9.2
2009	4.9	5.7	7.5	11.0	11.5	12.7	12.9	12.2	11.0	8.8	6.1	4.7	9.1
2010	5.4	6.3	8.6	10.7	12.0	13.1	13.1	12.9	11.1	9.3	6.9	5.1	9.5
2011	4.6	5.9	7.8	9.8	11.8	12.7	12.9	12.2	10.3	8.7	5.5	4.7	8.9
2012	4.2	5.8	7.5	10.5	12.4	13.2	13.0	12.3	10.7	8.9	6.4	4.7	9.1
2013	5.0	5.9	8.5	10.0	12.4	13.0	12.5	12.4	10.9	8.3	6.3	4.8	9.2
Ave	4.7	5.7	8.0	10.4	12.1	12.8	12.8	12.4	10.9	8.7	6.1	4.7	

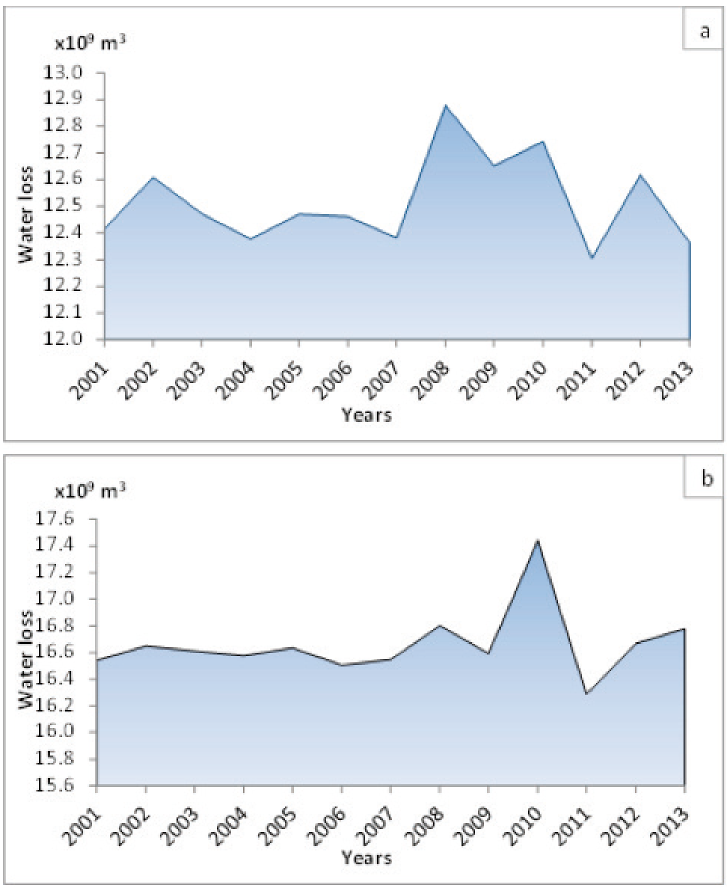

Figure (6): The total annual of water loss from Lake Nasser using satellite data from MERRA images (a) and climate data from ECMWF (ERA-Interim) (b).

3.3 Water Loss under climate change

This section investigates to study the expected water loss in the future compared with the historical estimations of water loss based on the same applied approaches in the previous sections. The total water loss in Egypt from agriculture and Lake Nasser have been estimated also in past/ current (2001-2013) form ECMWF (ERA-Interim) reanalysis data and near future time (2015-2025) from ECHAM 6 data and the results indicated that, the amount of annual water loss will be increase in the future with a noticeable values where in past/current the values were ranged from about 53 to 57.5 billion m3 per year while in the future time the values were ranged from about 61.5 to 66 billion m^3 per year, and the highest amount during the study period was observed in the year of 2021 as shown in Figure 7

In general, these results are in accordance with (Khalil *et al.,* 2015), which recorded that the total annual water loss from agricultural lands ranged from about 34.4 billion in the year of 2004 to 42.4 billion m^3 of water by the year of 2012. Also similar results obtained by (Simonneaux *et al.,* 2010) who reported that the area of cultivated lands in the delta region was 2.6 million ha according to MODIS images, which give total amount of ET about 30 billion m^3 and who achieved a quick extrapolation to the consumption of the whole Egypt, based on the relative surfaces of vegetation in the delta and in the valley. The vegetation in the valley which obtained from MODIS NDVI composite image covering whole Egypt and obtained total area of 3.9 million ha, including Delta, valley, and oasis. Thus a crude extrapolation of SAMIR ET estimates result about 44 billion m^3 of annual consumption. Similar results obtained by (Reda *et al.,* 2007) who reported that the average volume of the annual water lost by evaporation is about 12.5 billion m^3. To save more than one millions of cubic meters of lost water from Lake Nasser, 0.500 km^2 must be covered with Circular Foam sheets with an efficiency of coverage equal to 90%. In the same line (Shaltout and El Housry, 1997) reported that the water loss from Lake Nasser is one of the national problems in Egypt. The evaporated water loss ranges between 10 to 16 billion with m^3 every year, which is equivalent to 20 to 30% of the Egyptian income from Nile water.

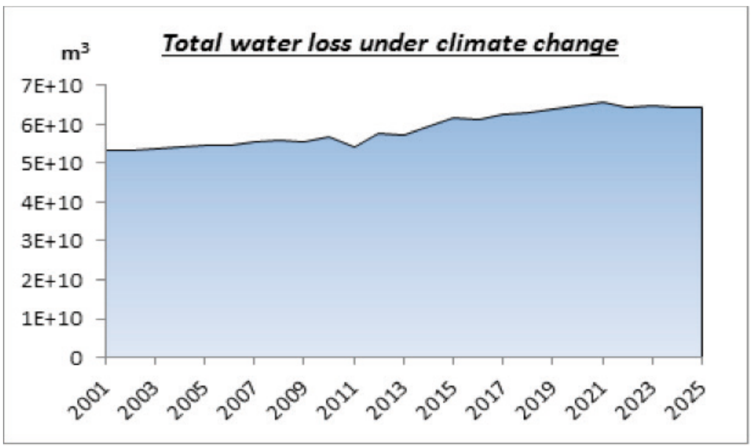

Figure 7 The total annual of water loss in Egypt under current (2001-2013) and near future years (2015-2025).

The remote sensing technique prove high accurate performance in monitoring and assessing the environmental and hydrological phenomena, and there are many studies also mainly relied on it, like, (Irmak *et al.,* 2011) who mapped the ETo at High Resolution in Great Plains environmental settings to understand water use in managed ecosystems on a regional scale. Also, (Patel *et al.,* 2006) reported that the satellite observations supplemented with meteorological data can give a unique ability to evaluate the actual evapotranspiration over large regions which is required for water balance and irrigation management. As well, (Wan, *et al.,* 2004) found that the big advantage in using surface temperature MODIS data for estimating ET where it can give a high accuracy of images associated with the spatial variability of this process at the regional scale.

The evaporation from the lakes also has significant environmental impacts. Among these is a total loss of wetland ecosystem which is located on the fringe of the lakes cause an increase in the lake water salinity and deterioration of the fisheries industry (Bastawesy et al, 2008).

4. Conclusion

Management of water by reducing the evaporation rates will optimize the amount of water that may perhaps support the ever-growing domestic, agricultural, and industrial demands. The different sources of data give different results of water loss. Egypt is not a rich country in terms of water resources, necessary measures should be taken to consider future water requirements of the country and to keep water losses as low as possible. Minimization of water losses in water distribution systems by using better and more reliable facilities like modern Irrigation System in agricultural locations and some chemical substances (e.g., Hexadecanol) or very thin wrapper materials can be used to cover especially small water surfaces, and other measures such as mechanical wind fences could also be established to prevent water loss due to evaporation.

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